VOLUME XX NUMBER 4 WHOLE NUMBER 155

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

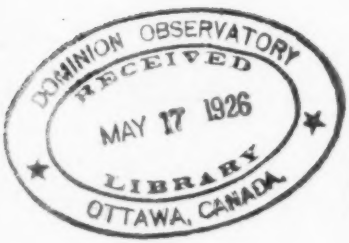
DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR
C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS
J. S. PLASKETT
Director of the Dominion Astrophysical Observatory, Victoria, B.C.
SIR FREDERIC STUPART
Director of the Meteorological Service of Canada, Toronto
R. MELDRUM STEWART
Director of the Dominion Observatory, Ottawa

PUBLISHED MONTHLY
(*Ten numbers per year*)

April-May, 1926



PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WHELDON & WESLEY LTD.
2-4 ARTHUR STREET, NEW OXFORD STREET, LONDON, W.C.2

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XX, No. 4 APRIL-MAY, 1926 WHOLE No. 155

Articles PAGE

Ancient Volcanoes of Southern Vancouver Island - *Robert Connell* 105
Einstein's New Universe - - - *J. H. Jeans* 118
The New Ideas in Meteorology - - *G. C. Simpson* 129

Review of Publications

Meteors, by C. P. Olivier; *Annual Tables of Constants and Numerical Data* - - - - - - - - 143

Notes and Queries

From "The Humorist"; A Brilliant Aurora; Russia to Have the Largest Refractor; Further Ether Drift Experiments. *C.A.C.* 146

Meetings of the Society

At Toronto, February 23, March 9, March 23 - - 149

Upon request, made previous to publication of article, contributors will be supplied free either with fifty copies of the issue containing the article, or with the sheets containing the article stitched in a printed cover. If separate reprints are desired the cost will be as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies	$3 50	$6 50	$ 9 50	$10 00	$13 00	$16 00
100 copies	4 00	7 00	10 00	11 00	14 00	18 00
200 copies	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Business correspondence, remittances, etc., should be addressed to H. W. Barker, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

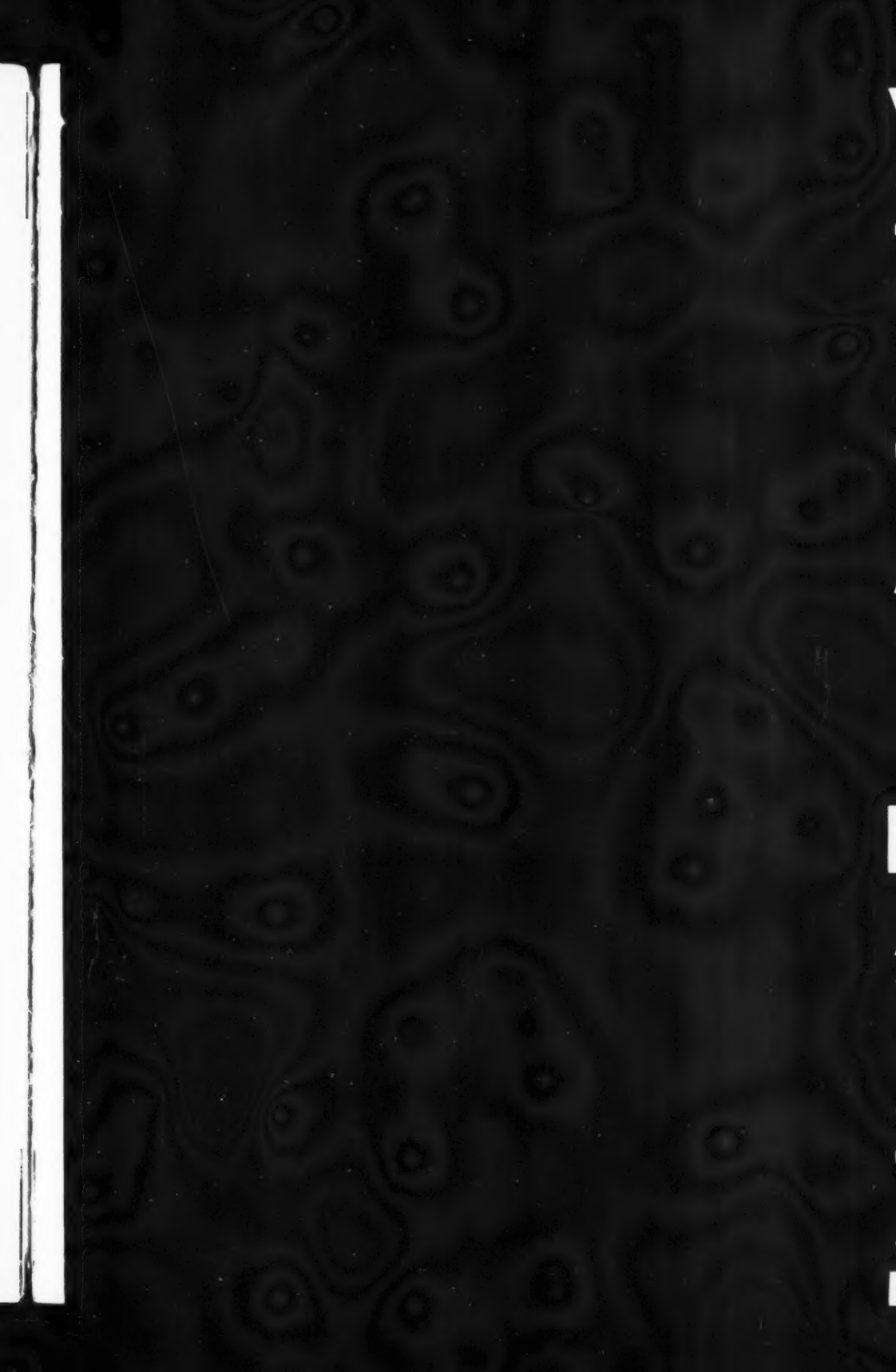
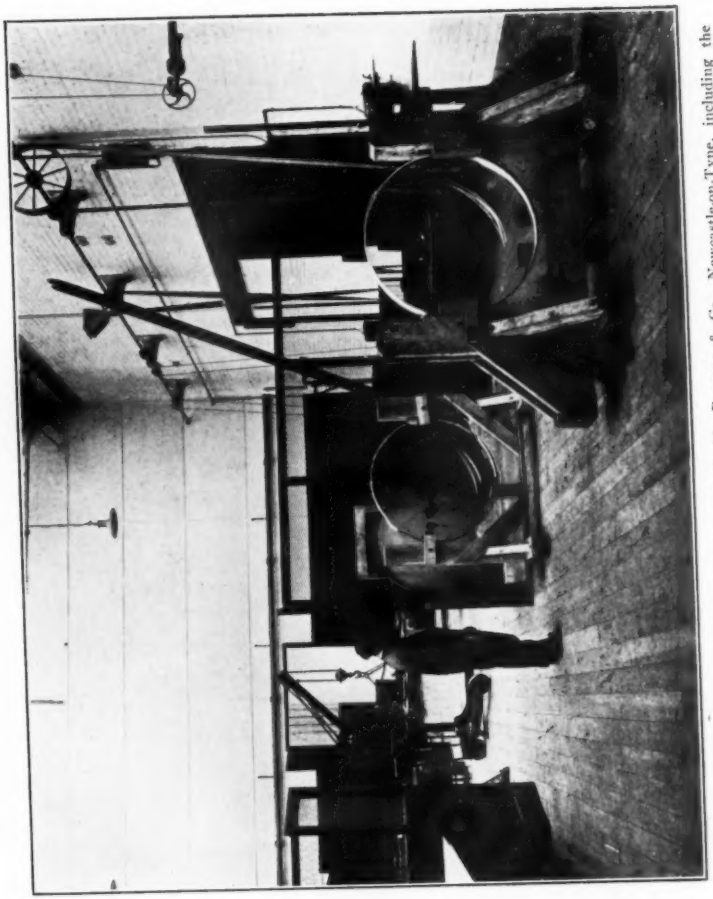


PLATE I.



A portion of the Optical Works of Sir Howard Grubb, Parsons & Co., Newcastle-on-Tyne, including the two 42-inch glass discs for the Russian telescope (see page 146).

A portion of the Optical [illegible] two 42-inch glass discs for the Russian telescope (see page 1457)

PLATE II.

Fig. 1 (above). Columnar Basalt: Quarry at Albert Head. Metchosin Volcanics.
Fig. 2 (below). Pillow Lava with altered Glass interfilling: Quarantine Station, William Head. Metchosin Volcanics.

PLATE III.

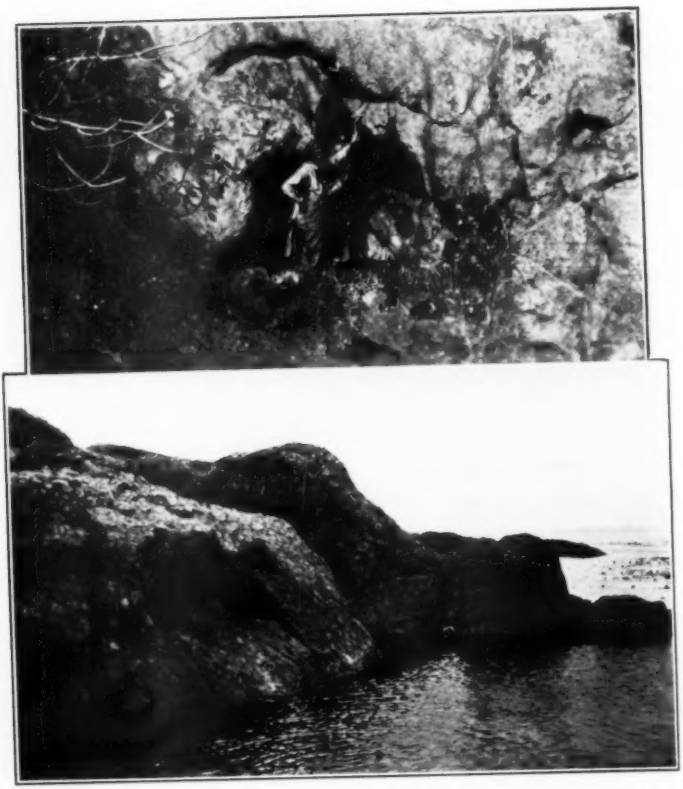


Fig 3 (above). Pillow Lava: Pillow 15 feet long above Hammer: Metchosin Volcanics in Sooke Hills.

Fig. 4 (below). Epidotic Pillow Lava with interfilling of Jasper. Quarantine Station, William Head. Metchosin Volcanics.

PLATE IV.

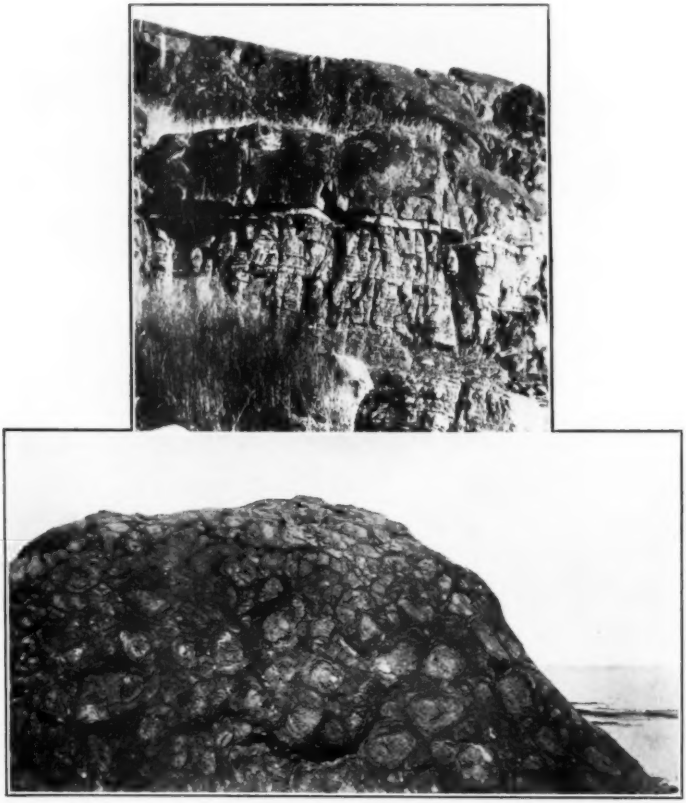


Fig. 5 (below). Epidotic Pillow Lava with Jasper Interfilling. Quarantine Station, William Head. Metchosin Volcanics.

Fig. 6 (above). Bed of Cherty Tuff containing Fossils. Quarantine Station, William Head. Metchosin Volcanics.

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. XX, No. 3 APRIL-MAY, 1926 Whole No. 155

ANCIENT VOLCANOES OF SOUTHERN VANCOUVER ISLAND*

By ROBERT CONNELL

THE idea of a volcano is one which makes a strong appeal to the imagination, for there is necessarily always something of the awesome about the spectacular movements of the earth's crust. The popular notions of volcanic activity, however, are largely influenced by the accounts of eruptions contained in press despatches where scientific accuracy is not to be expected. The "flames and smoke" give an entirely erroneous notion of the phenomena as they actually are, though it is true that superficially there is some justification for the use of such terms. I shall therefore first give some account of the more important products of volcanic action, the phenomena associated therewith, and the crustal forms which ensue; and all as briefly as possible.

Of volcanic products the most important is the liquid or molten rock-material, since of it is composed the whole range of igneous rocks, whether ejected at the surface as lava or injected into the existing crust. The superficial outpourings of molten matter vary in character and consequently in form. Some lavas are highly siliceous and are in consequence very viscid, since they cool at a comparatively high temperature. The component minerals do not easily crystallize and the structure of the lava internally is glassy predominantly. Lavas which are low in silica and high in

*A paper read before the Victoria Centre, November 16, 1925.

iron and magnesia cool more slowly, are therefore more liquid, and show an almost entire absence of glass. Their minerals, even when inconspicuous to the naked eye, are distinctly crystalline in form under the microscope. These slow-cooling lavas are characteristic of Kilauea in Hawaiian Islands, and from a study of them there much light has been thrown upon the older volcanic extrusions.

To water may be ascribed the next place in importance, although its volcanic occurrence is at first as invisible vapor and then, upon its escape, as clouds of condensed steam. Water in the form of vapor is the predominant gas of eruptions and takes an active part in the production of the fluidity of lava as well as in the explosive action which is so marked a feature of the majority of spectacular volcanoes.

The explosive power of water in its gaseous form gives rise to a modification of the lava of very great importance since it constitutes a considerable portion of the ejected material and in some cases the whole of it. The lava in the crater or neck of a volcanic opening cools during a temporary cessation of activity and a crust is thus formed which may be glassy or stony or possess a mixture of both conditions. On the development of a fresh paroxysm this crust is blown to pieces and the fragments discharged into the air. They may vary in size from the finest dust requiring the aid of the microscope for its analysis to large blocks several feet in diameter. The dust-like form is known as "ash" or "tuff", a somewhat coarser variety is called "lapilli", while the mixed and angular fragments constitute "agglomerate" or "volcanic breccia". When the lava surface is frothy in texture the fragments from its dispersal are known as "pumice". It is generally formed from the pale and acid lavas of siliceous character and so full of air-cavities is it that it floats with ease. The basic or less siliceous lavas have often a rough cindery appearance like that of "slag" from a furnace, and this is but a coarser kind of pumice and like it is a superficial froth or scum. Such matter, often fragmental, is called "scoria".

Volcanoes which emit almost entirely lava, especially the more liquid kinds, have low slopes: Kilauea is an excellent example of

this form. The steeper outlines which we associate with Mount Baker and Fuji-yama are the effect of the piling up of successive outpourings of lava and ash, the latter even predominating. Such volcanic peaks are known as "composite cones" and they harmonize best with the popular notion of a volcano's form.

It will thus be seen that there are in a volcano no products of "combustion"; that the "ashes" are the effect of explosion, not of burning; that the only place for flames is in the ignition of inflammable gases on the surface of the molten lava, an inconspicious phenomenon at best; and that the clouds of "smoke" are composed of condensed steam laden with the finely divided ash and reflecting the red-hot surface of the crater's contents.

All lavas are, however, not ejected from craters. In some cases they ooze out from fissures in the crust of the earth and slowly flood the surrounding country. Thus the great lava-plains of the Deccan in India, of the Snake River country to the southeast of us, and of northern Ireland and western Scotland are supposed to have been poured out. Along these fissures small cones are sometimes built up, and explosive action takes place with its accompaniments, but these are secondary phenomena. They are well-known in Iceland as well as in the Snake River district. Mixed eruptions of this type characterized some of our local volcanic activities in times past.

The most ancient volcanic rocks on Southern Vancouver Island, and probably on the whole Island, are to be seen along the E. and N. Railway cuttings as the line rises from the Goldstream Valley along the Malahat, on the western sides of Mt. Skirt and Mt. Finlayson, and at Gonzales Hill, Victoria. The lavas and tuffs of which they are composed have been much altered, but their essential characters can still be read. Gonzales Hill is composed of a pale felsitic rock with the flowing structure of the original viscid lava still clearly visible. After stiffening the lava was again subject to movement so that fragments of the cooler matter were drawn out and re-cemented in the ground-mass. The rock is now best classed as a dacite or quartz-andesite of originally glassy character. These Malahat volcanic rocks are interfolded with the Leech River slaty schists which extend through to the west coast

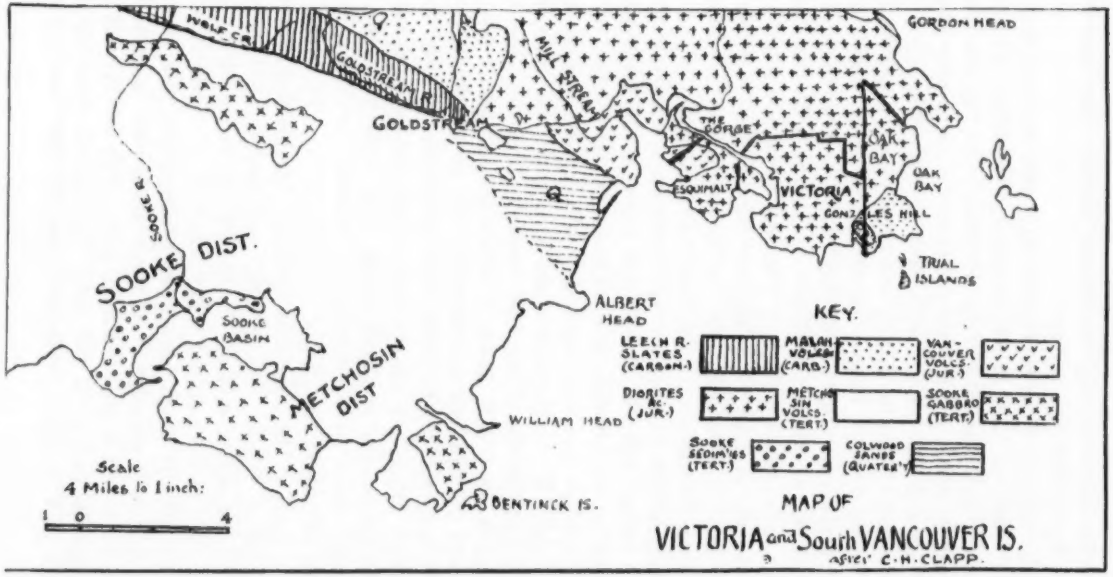
of the Island in a gradually widening belt. These latter are placed by Clapp in the Carboniferous from their resemblance to rocks unmistakably of that age upon the mainland of British Columbia, and from their being intruded by igneous rocks of Jurassic age. Upon the Leech River sediments the Malahat eruptions deposited great accumulations of coarse and fine "ash". Some of the beds resemble sandstone in their texture and are composed of felspar and quartz in angular pieces with fragments of andesite and pieces of carbonaceous schist of varying size. Beds of coarse agglomerate at Gordon Head, north of Victoria, which are cut by wide dykes of banded trachytic andesite, are possibly related. The Gonzales Hill andesite penetrates and shatters around the base of the elevation carbonaceous schists like those of Leech River.

During early Jurassic times there was another outbreak of volcanic activity which was widespread on Vancouver Island and adjacent islands to the north. Its lavas and tuffs have been greatly altered and eroded, but they still form a prominent part of the Island's interior. Associated with them are beds of limestone or rather, since it has been re-crystallized, marble. Around Victoria none of these have yielded fossils, but at the south end of Cowichan Lake the remains of corals and other marine organisms have been found. It is therefore possible for us to picture the presence in the waters now occupied by Vancouver Island and its neighbours of an archipelago of volcanic islets built up upon the submarine floor and girdled with coral reefs, very similar in every way to the island groups of the Pacific girdle of to-day. At a point on the north shore of Cordova Bay there is an outcrop of lavas which show the "pillow" structure often found in connection with submarine flows, but as this is more fully developed in a younger series of rocks I will defer description of its character till we come to the Tertiary volcanic rocks. Owing to their erosion the Vancouver Volcanics, as these Jurassic volcanic products are called, do not in the neighbourhood of Victoria markedly affect the topography. They are quite overshadowed by the dioritic rocks which have intruded them and whose deep-cooled masses now towering in hills of five hundred to fourteen hundred feet in elevation demonstrate the powerful erosion to which the over-

lying volcanics were subjected during Tertiary times and to a less extent during the Age of Ice.

It is when we come to Tertiary days that we stand upon surer ground, since we have in the Metchosin, Sooke, and Jordan River districts a well-preserved series of lavas, tuffs, agglomerates, and sedimentary rocks, the last formed from the lavas soon after their extrusion and interbedded with them. The early part of the Tertiary period was marked by extensive volcanic activity in many parts of the world. Then were formed the great basaltic plateaux of Northeastern Ireland and of Mull, Skye, and the Inner Hebrides of Scotland, of which the Giants' Causeway and the Caves of Staffa are renowned portions. The same sheets are found forming the sea-cliffs of East Greenland and Spitzbergen. On the shores of the Straits of Juan de Fuca the Eocene basalts are found on Vancouver Island and in the State of Washington opposite. All the characteristic members of the Metchosin Volcanics may be seen within twenty miles of the city of Victoria. In many ways the low cliffs of the seashore give the finest exposures since the waves keep the rocks free from concealing lichens and mosses, and by their erosion of the glacial deposits have uncovered fresh surfaces. But in addition there are the roadside rock-cuts, the railway cuttings of the C.N.R., some of which are of considerable magnitude, and the long and winding rock-cuts of the Victoria Water Works from the city to Sooke Lake, a distance of over 40 miles. At Albert Head is a quarry from which rough stone was taken for the Breakwater at Ogden Point. To local geologists it has furnished some good examples of zeolites, secondary crystals formed in cavities.

The lavas of the Metchosin series are basalts, dark heavy rocks composed of felspar, rich in lime, and augite, an iron silicate. Olivine, a common mineral in basalts, is absent from all the specimens I have examined. The augite is very commonly altered to green chlorite which imparts its colour to the rock. Yellowish green epidote is abundant. At times whole rock masses are replaced by it. It is also found in little nests of crystals in the amygdaloidal cavities of the rock. The typical basalt is a fine-grained rock of whose component minerals little else is visible to


WOLF CR.
GOLDSTREAM R.
GOLDSTREAM
MILL STREAM
GORDON HEAD
THE GORGE
OAK BAY
ESQUIMALT
VICTORIA
GONZALES HILL
OAK BAY
TRIAL ISLANDS
SOOKE R.
SOOKE DIST.
SOOKE BASIN
METCHOSIN DIST
ALBERT HEAD
WILLIAM HEAD
BENTINCK IS.
KEY.
LEECH R. SLATES (CARBON.)
MALAHAT VOLCS (CARB.)
VANCOUVER VOLCS (JUR.)
DIORITES &c. (JUR.)
METCHOSIN VOLCS. (TERT.)
SOOKE GABBRO (TERT.)
SOOKE SEDIM'TS (TERT.)
COLWOOD SANDS (QUATER'Y)
Scale
4 Miles to 1 inch.
1 0 4
MAP OF
VICTORIA and South VANCOUVER IS.
after C.H. CLAPP.

the naked eye than the gleaming cleavage planes of the felspar prisms as the light falls on them, but not infrequently the finer grained type passes into a typical dolerite (diabase) of distinctly coarse grain. It is very difficult to distinguish between the external lava flows and the intruded sheets or sills owing to the confusing way in which the intergrading of coarse and fine textures occur in plainly surface-cooled rocks. Columnar structure is confined, as far as my experience goes, to the immediate neighbourhood of Albert Head, where it is found well developed in places. The columns vary in diameter from nine or ten inches to four.

By far the most striking and characteristic structure found among the lavas is that known as "pillow-lava". Travellers through the district, however unobservant they may be, can scarcely fail to be struck by the curious appearance as of petrified sand-bags in heaps which greets them for miles along the roads and railway. The "pillows" lie upon each other in a manner which shows that at the time of their deposition they were still plastic, for the underside of the upper "pillows" has a concavity corresponding to the convexity of the ones below. Their average length is about twelve to fifteen inches, but at times they greatly exceed these dimensions. Occasionally they attain a length of fifteen feet. On the other hand they are often only a few inches through. Pillow-lavas are found in volcanic formations of all ages and their mode of origin has been observed in the Hawaiian lavas of to-day. The description of their production given by Dr. Hatch is as follows: "It appears that lavas of a certain composition instead of parting at once with their steam, when emptied on the sea-bottom, swell up like a sponge, and retain a great part of the steam in vesicular cavities, thus greatly reducing their density. Moreover, such lavas on eruption seem to be in a true spheroidal condition and, since each spheroid or pillow as it becomes detached is jacketted by a shell of steam, the floating mass forms on the sea-bed a mobile sheet of rolling spheres, seldom touching one another until they cool. Lavas possessing this structure usually consist of detached pillows piled one over the other, the intervening spaces being filled with the sedimentary material of marine origin; thus they are often associated with radiolarian cherts."

The pillow-lavas of the Metchosin volcanics have in some cases, probably in a majority, their interspaces filled with a dark green and rather soft material which on microscopic examination proves to be a very highly altered glass, the result of the sudden cooling of the outside of the pillows. It now consists almost entirely of green chlorite, but there are traces of the original glassy flow structure. In many places, however, the interstices contain wisps of sedimentary material of a yellowish colour on the weathered surface. Frequently there may be traced the marks of stratification, and the source from which the included matter has come is thus evidently traceable to certain isolated masses of sedimentary rock which are invariably found in the near vicinity.

These have been very fully described in the Geological Survey Memoir No. 96, on the "Sooke and Duncan Map-Areas, Vancouver Island", where Clapp names them "cherty tuffs". They are composed of very fine volcanic ash accumulated on a quiet sea-bottom, since the stratification shows no signs of disturbance by waves. In the fine muds thus formed are the microscopic remains or casts of minute animals, such as foraminifera and radiolaria, though specific identification of them has not been made. From their occurrence in similar cherts associated with pillow-lavas all over the world it is not surprising that they are found in these deposits too. An extremely careful examination of the weathered surface and of the inner faces of small crevices has resulted in the finding of a very perfect cast of a species of Nodosaria and of a number of fragments of the tests of Echinoids. In the case of both, the fine sediment has preserved the markings with wonderful precision. The cherts themselves are found scattered over an area of many miles, but in no case are more than fragments left. The largest, in the neighbourhood of, and at William Head Quarantine Station, are not more than 150 feet long and the greatest thickness 20 feet. In every instance they have been broken off by the invasion of lavas, which have in many places bent them. At the finest exposure near the extreme point of William Head the upward course of the lava and its horizontal spread over the chert beds is very clearly seen. The chert is slightly baked at the edge and top while the lava has steam cavities at right angles

to the surface of the invaded rocks. The horizontal thickness of the chert at the point where the invasion is thus exposed is under three feet, so that there would appear to be only a "facing" of it. Fifty feet or so further down near low tide-mark a small fragment of the chert re-appears. A little further to the west another striking exposure occurs. The chert is here curved at each end and slightly overturned, showing a horizontal movement of the disturbing lava. There is a remarkable show of worm-casts on the surface of one of the layers with other traces apparently of animal organisms. While no doubt much of the matter of these tuffs is silica secreted by living creatures of those days with some possible admixture of fine eroded matter, the bulk is evidently composed of volcanic ash, and witnesses to powerful explosive action at an early stage. For the discovery of fossiliferous remains in the cherts the chief credit is due to Mr. I. E. Cornwall of William Head, who has been assiduous in the search.

A rather unusual pillow-lava occurs on the south shore of William Head alone. The pillows are less flattened than they ordinarily are and are of a decidedly yellowish-green colour from the extensive replacement in them of the original minerals by epidote. In addition the filling around them is of a bright red colour from the presence of iron oxide in the silica. The contrast in colour between the green pillows and the red filling is very striking, and at times the structure seems almost artificial. The red substance is of undoubted sedimentary origin and organic forms can be indistinctly made out in microscopic sections.

The lavas and the cherts are cut by "dykes" or fissures in which molten rock hardened in making its way outward. These dykes are at times less durable than the rock on either side and are consequently more easily weathered or eaten into by the sea where they occur along the shoreline. They are often distinguishable by a rude cleavage at right angles to the enclosing walls after the manner of columnar structure. They are generally composed of dolerite which differs from the ordinary basalt only in the coarser grain of the rock from its slower cooling. Along the edges of the dykes, however, where the intruded matter was more quickly cooled by the walls of the fissure up which it welled, there is

invariably a narrow selvedge of very fine-grained basalt. There are many narrow dykes, so narrow in some cases that they might almost better be described as "veins", which have this fine structure throughout, and where they have sent off tongues into the sedimentary rocks they have traces of glass. The connection of the dykes with the superficial flows of lava can sometimes be made out with great certainty, but this chiefly occurs where sediments or deposits of explosive origin are cut and overflowed.

I have already referred to the cherty tuffs. These are but a small portion of the deposits of fragmentary material. Along the northeastern boundary there are coarse agglomerates of considerable extent. Further west they are met with along the upper flanks of Mt. Helmcken and across the valley of Braden Creek on the rocky heights cut by the Sooke Lake pipe-line. They occur on Bluff Mountain west of the Sooke River and on Buck Hill above Pedder Bay. There are also beds of finer matter, yet still of a coarse type, near the summit of Mt. Helmcken and along the shores of Albert Head. The latter deposits, which may be described as "coarse tuff", frequently contain fragments of glass or tachylite, such as is not now met with in the rocks of massive type. It is interesting to note that Mr. Clapp reports the finding of similar glass particles in the Sooke sandstones at Muir Creek. The beds at Albert Head are the most varied in character and from the manner of their association Mr. Clapp has been able to demonstrate their origin and history.

West of Albert Head proper a smaller point projects from the coast and there is thus formed a small bay in the entrance to whose shallow waters are a few small islands composed of pillow-lava. On the shore of the bay at its eastern end there is an exposure of agglomerate whose hard surface has been polished and scratched by the glacial ice-cap. It is composed of sharply angular fragments of basalt of sizes varying from mere specks to several feet in diameter. The agglomerate is much less altered than that of other localities and there can be no doubt that Mr. Clapp's diagnosis is correct and that there is here the exposed and eroded "neck" of one of the Tertiary volcanoes. Such "necks" are filled either with the cooled residue of lava or, as in this case, with ex-

plosively ejected matter which has fallen back into the vent and become cemented in the still viscous mass within. Close by are beds of coarse tuff which are the remains of the accumulations around the vent, while further off is a bed of scoriaceous fragments which must once have constituted part of the bubbling surface of the liquid lava. There are sedimentary beds which range from compact fine-grained basaltic debris to coarse gravels containing "cobble-stones" several inches in diameter. In places these beds contain fossil shells. At one point just above the present high water mark I stood upon the gently sloping surface of the old beach gravel and saw at my feet an ancient oyster valve imbedded in the now solidly compacted rock. At another spot the detritus is pale in colour and contains many small fragments of shell. The principal fossil bed, however, is found in a small cove where a dark tough basaltic sandstone contains a layer of shells three feet or more in thickness. They are principally those of a species of Turritella but there are a few bivalve shells included. The shells are well preserved but owing to the toughness and homogeneity of the rock it is by no means easy to obtain good specimens.

The importance of the discovery of these fossils is shown in the result of their identification, which established their Eocene character, and in consequence assigned the volcanics to the same age, since the sedimentary rocks are clearly interbedded with them. Previously to this identification the lavas and tuffs of Metchosin and Sooke had been regarded as a less altered and probably younger suite of the Vancouver volcanics. In addition, the profound fault which separates the Metchosin rocks from the Leech River slates to the north was thus shown to be of Tertiary development. This great overthrust by which the older slates were pushed over the younger volcanics is ascribed by Clapp to the Lower Oligocene, or, in other words, it occurred shortly after the expiration of the period of volcanic activity, and in association with the phase of intrusive gabbro rocks which penetrated the shell of cooled lavas and tuffs.

While the mineral content of the basalts is singularly uniform throughout the whole range of the Metchosin basalts and dolerites,

there is considerable variation in their structural relations and in the character of the resulting rocks. To some of these I have already referred, the pillow-lavas and columnar basalts. The peculiar structure known as "amygdaloidal" is exceedingly common although confined chiefly to the borders of flows. The bubbles contained in the liquid lava upon solidification appear as cavities which may be rounded, oval, or irregular. In some cases they are drawn out in long tube-like forms, parallel or branched. Unfilled such vesicles are characteristic of scoria, but when through the percolation of waters saturated with mineral substances, often leached out of the rock itself, the cavities become filled, the resulting appearance has earned for itself the name of "amygdaloidal" and the more or less completely filled openings are called "amygdales", from the almond-like appearance of the more oval forms. Occasionally where a surface of rock has escaped the operation of the ice of the Glacial period or the extremer operations of weathering by its protection in some recess or cavity the "ropy" form of the original lava may be seen as a twisted flow-structure "in relief".

A consideration of the immense mass of rock removed by erosion since Eocene times enables one to understand the difficulty of finding structures comparable to those of more modern volcanic localities. The "lie" of the lava beds is more distinctly seen immediately west of Goldstream where the bare hills that surmount the valleys on each side reveal their structure distinctly. There are evidences of faulting in places, but even allowing for this, which would appear to have caused no serious displacement, it is easy to see that somewhere between five and nine thousand feet must have been removed by erosion. Remnants remain, it is true in the hills referred to, but their greatest height does not exceed 1800 feet. We have therefore only for our investigation the roots, so to speak, of the volcanics or the deeper beds of flow, intrusion, and tuff, and in the case of Albert Head a centre of activity with its shores, once smothered in later lava and then denuded to its present state.

Perhaps the most remarkable feature of the Metchosin volcanics is the absence of limestones. A few small fragments have been

found, it is true, in the neighbourhood of Albert Head and Parry Bay, but quite insignificant in amount. They may, however, be remains of larger bodies which once existed near the present shore-line. In this respect then, so far as our present knowledge goes, there was a marked difference from the environment of the Vancouver volcanics, which as we have seen had associated with them coral reefs. The existence of the Turritella bed shows that there were pauses of sufficient length between the active periods to permit of the growth of organisms and the accumulation of their remains as well as of the erosive products of the shore-line and interior; and the climate of the Eocene was supposedly in these latitudes much warmer than at the present day, so that conditions would seem to have been just as favourable to the coral-builders as in the earlier volcanic times. From the situation of the known beds of cherty tuff it is not likely that any traces of lime-secreting organisms will be found, if ever, in the vicinity of the present coast-line and the larger valleys opening into it. It is worthy of note that specimens of coral have been found by Mr. I. E. Cornwall and myself in the sedimentary rocks of Sooke. One of these, found by Mr. Cornwall, has been described by Dr. Clark in his monograph on the fossils of these deposits in the University of California Geological series and named Siderastrea vancouverensis by Dr. Vaughan. The Sooke rocks are ascribed to Upper Oligocene times, when according to Dr. Clark the "temperature conditions were very similar to those at the present time in the same region", since the "Sooke fauna contains the ancestral elements of the fauna now living" there. Yet the coral referred to is one of the reef-building madrepores.

The photographs illustrating this paper were taken by Messrs. I. E. Cornwall and J. T. Barnes, to whose kindness in permitting their use I am indebted. I must also express the obligation I have long been under to Mr. C. H. Clapp's Memoirs on the Victoria, Saanich, Sooke, and Duncan districts.

EINSTEIN'S NEW UNIVERSE*

By J. H. JEANS

SOME of us may remember the story of the children who played truant in order to explore the regions where the rainbow ends. After travelling all day, up hill and down dale, they had to admit failure of the most thoroughgoing kind—the rainbow was to all appearances no nearer than when they started. Really scientific children might have thought of estimating their rate of approach to the rainbow by measuring the angle it subtended. If they had measured it in the morning it would have been 42° 23′; it would have been 42° 23′ at noon, and again at night it would still be precisely 42° 23′. If they had done this they must have felt that they were the victims of extreme bad luck, for they had clearly seen the rainbow in front of the nearest hill when they started out; could there be some sort of conspiracy on the part of rainbows, hills, and indeed the whole scheme of nature, to prevent their getting close up to that rainbow?

In the year 1905 the world of physicists was engaged in a pastime which was, in many respects, very similar to that of chasing rainbows. They believed light to travel through an ether with a speed of 300,000 kms. a second. If the solar system were travelling through this ether at a speed of, say, 1000 kms. a second, it would partially overtake light travelling in the same direction, so that this light ought to appear to travel at only 299,000 kms. a second. On the other hand, light travelling in the opposite direction ought to appear to travel with a velocity of 301,000 kms. a second. This suggested an obvious means of discovering both the speed and

*An address delivered by Dr. J. H. Jeans, the President of the Royal Astronomical Society on presenting the Gold Medal of the Society to Professor Albert Einstein, for his researches on Relativity and the Theory of Gravitation (February 12, 1926).

direction of the earth's voyage through the ether—indeed, it was every bit as obvious as the children's plan for exploring the foot of the rainbow. Experiments were designed to utilise this principle and were tried time after time, not in one form only but in many. And time after time experiment gave the answer that the velocity of the earth through the ether was zero, or at least, to put it in another form which was at that time thought to mean precisely the same thing, the velocity of light relative to the earth was the same in all directions. No doubt it was conceivable that on the occasion of the first experiment the earth really might have happened to be at rest in the ether, but it was quite inconceivable that this should be the case every time; indeed, the earth's orbital motion alone required a variation of some 30 kms. a second, and all the experiments were capable of detecting far smaller variations than this. At first glance it looked as though the earth must be carrying its own private ether about with it, and I suppose this view would have prevailed had it not been for the astronomers, who were ready with an aberration-constant which at once, and, I think, irrevocably, dismissed the possibility of an ether being dragged about with us. Incidentally this episode provides an often overlooked instance of the services of astronomy to the other sciences and to the growth of knowledge in general. The physicists on Jupiter may still believe that a luminiferous ether exists which follows Jupiter about wherever it goes; the reason is that there are no astronomers on Jupiter to put them right, their permanent blanket of clouds not encouraging this profession.

I forget the end of the story of the rainbow quest, but am prepared to provide an entirely unauthoritative ending. After the children had got completely tired in their bodies and still more completely bewildered in their wits, they rested for a long time, until they encountered a magician. He was not in the least the conventional magician, ponderous of speech and with a long white beard; indeed he was a young man of twenty-six, extraordinarily simple and unassuming in all that he said. What he said in brief was this: "I can tell you what is the matter. You have started to chase the rainbow on the supposition that it is a material arch; in actual fact it is all in your own eyes. Gretchen sees one rainbow, and Hans sees a quite different one. But if Hans walks up to

where Gretchen is standing, he simply changes his rainbow for hers; you don't get any nearer to a rainbow by walking this distance, because there isn't really anything for you to get any nearer to. The angle you have been measuring must always stay at 42° 23′; it is fixed there by the unalterable laws of nature, and children can't alter these by walking about." As the children were tired, and the young magician had perhaps expressed himself in rather unfamiliar ways, they didn't at first quite understand what he meant. But then another magician whose name was Minkowski came along and he made it all seem much simpler; he said it was quite true that each child carried its own rainbow about with it, but that behind the subjective vision of the rainbow was an objective reality consisting of a shower of raindrops. These raindrops were the same for everybody, but out of the whole lot each person's eye selected, or rather the sunshine selected for each person's eye, a small group of drops which appeared to him to form a bright arch. If all space were filled with children standing in different spots, then the aggregate of all the raindrops seen in all the children's eyes would constitute the reality behind the whole phenomenon, a shower of rain. When the second magician put things in this way the children began to understand; they saw that the first magician, whose name was Einstein, had been right.

I doubt if the Society has ever had its Medallist introduced to it in so disrespectful a way before, but my little parable may remind you of the way in which our present Medallist made his entry into the scientific world, and also of the way in which the scientific world made their entry into the changed universe in which science moves to-day. Time and space as separate entities, the time and space we wrote about and thought about previous to 1905, have gone, or, as Minkowski puts it, have become shadows, while only the product of the two remains as the framework in which all material phenomena take place. Time and space separately may mean something to us subjectively, but Nature knows nothing of them until they have been multiplied together into a four-dimensional space-time continuum; it is in this that she has set her laws. If I have seemed to treat Einstein's great early work too lightly I would plead, first, that it has already suffered enough serious exposition, and, second, that only really great work permits of being

treated lightly, and that it is well to take a chance when it offers itself. But let not the lightness of treatment be thought to imply lightness of esteem for the work. By his single 1905 paper, Einstein started a revolution in scientific thought to which as yet we can see no end, to which, indeed, we can hardly yet imagine any end. Had he written only that one paper his position as one of the great figures of science would, in my opinion, have been secure. He would perhaps not have been awarded the Gold Medal of our Society, but that would be because he had not yet become an astronomer.

If the magicians had given the right explanation of the rainbow, then everything the children saw in the rainbow ought to admit of explanation in terms of the ultimate reality provided by the shower of rain. Obviously there would have been something radically wrong if Gretchen had seen a circular rainbow while Hans, standing by her side, had seen a square one; something wrong, too, if Gretchen had said that the colours ran from red to blue as you passed inwards, while Hans said they ran from blue to red. And in the same way if Einstein and Minkowski were right about time and space, there must have been something radically wrong when Isaac Newton had said that every particle in the universe attracted every other particle with a force that varied as the inverse square of the distance, and again when he had said that the path of a planet about the sun was an endlessly repeated ellipse. When the last of these statements, for instance, is expressed in terms of the four-dimensional framework which Einstein and Minkowski regarded as the ultimate objective reality, it is found to make sheer nonsense, to be inconsistent with itself. Viewed in that framework an endlessly repeated ellipse becomes a sort of helical curve, a spiral staircase climbing up into eternity, whose projection on one particular cross-section is the single ellipse in question. View it from any angle you like and it is still a helical curve, but project it on some other cross-section and you will find that the radius vector relative to the sun no longer describes an endlessly repeated ellipse. In brief, the Newtonian law of gravitation could not be true, because it could not be expressed in terms of the ultimate four-dimensional reality in such a way as to be true for more than one person at a time. When our Medallist

had this brought to his notice he at once became an astronomer.

His task, rather a heavy one for the first piece of work of a young apprentice to astronomy, was to find out what was the matter with Newton's law of gravitation and to put it right. Of course, in a sense, there wasn't very much wrong: Halley's comet had come back when it was expected, and Jupiter's satellites could be seen every night, exactly as the pictures in the Nautical Almanack predicted that they ought to be seen if Newton had been right, and all the planets seemed actually to be describing endlessly repeated ellipses, except that Mercury wandered very, very slightly from his proper place. And yet, in another sense, there must be everything wrong with a law that didn't fit properly into the four-dimensional reality, or at least there was as much wrong as the difference between truth and error, which the true man of science regards as the biggest magnitude with which he ever has to deal. And just as Kepler, starting from the established error of eight minutes of arc in the observed position of Mars, had set out "to construct a new theory that will explain the motions of all the planets," so our Medallist set to work to construct a new theory which was incidentally to explain the motion of the planets, but was destined also to change our whole interpretation of the fundamental significance of these motions.

Every astronomer is familiar with this part of Einstein's work. By 1915 he had found the modification needed in Newton's view of gravitation, and had shown that the orbit of a planet, instead of being the impossible endlessly repeated ellipse, was an ellipse which kept slowly turning round in its own plane. He had also found that the theoretically predicted rate of turning for Mercury was exactly the 43″ a century by which Leverrier had found that that the planet's perihelion advanced over and beyond the advance caused by the pull of the other planets. He announced two further physical consequences of his theory. Rays of light passing through a gravitational field ought to be bent by a calculable amount, 1″.745 for light which has just grazed the sun's limb; and spectral lines emanating from atoms in a gravitational field ought to be displaced towards the red, the displacement of lines from the solar photosphere being that corresponding to a velocity of 0.634 kms. a second, or, say, 0.008A at the cyanogen band λ3883. Newton

had queried in his optics whether rays of light would bend in obedience to gravitational force, but Einstein was the first since Newton to make any definite physical predictions arising out of a theory of gravitation.

Our two British expeditions put the first of these predictions to the test at the 1919 eclipse, and, as we know, brought back the news that the prediction was amply verified. The testing of the second prediction was a more difficult matter, not so much because the small displacement of 0.008A was difficult to measure as because it was masked by bigger displacements of unknown amount. Even to-day the problem can hardly be said to be solved with absolute finality so far as solar light is concerned, although probably Evershed, St. John, and others have done all that it is possible to do. But the prediction which it was found almost impossible to test by the light of our sun has been tested by the light of one of the faintest of stars. Sirius has as companion a smaller and far fainter star which describes an orbit round it. Its effect on the motion of Sirius shows its mass to be 0.85 times that of the sun, and its distance is for all practical purposes the same as that of Sirius. The amount of light it emits is so small that Seares had calculated its radius to be only about 20,000 kms., or one thirty-fifth of the radius of our sun. Now Einstein's theory predicts a shift proportional to M/r, so that whereas the predicted shift in the solar spectrum corresponds to a velocity of only 0.634 kms. a second, the light from the companion to Sirius ought to show a shift corresponding to a velocity of 20 kms. a second, something like a third of an angstrom. Here then was a shift whose magnitude was suitable for measurement. The measurement was undertaken at Mount Wilson, and the observed shift was found to agree almost exactly with that predicted by theory. This experiment not only established the validity of Einstein's theory of the gravitational displacement of spectral lines, but also showed its usefulness as an instrument to be utilized by the practical astronomer in his everyday work.

The ultimate importance of Einstein's work was not, however, that it gave astronomers new tools for the measurement of stellar diameters, or for the prediction of the position of Mercury; it was not even that it gave the true law of gravitation; it was that it gave

a new conception of the meaning of gravitation and of gravitational force. Strictly speaking, Einstein did not amend Newton's law of force; he abolished it. He put something else of a quite different nature in its place, something which was consistent with itself when looked at in the four-dimensional continuum and which agreed with the observed facts of nature, including the then untested bending and reddening of light. At first he had tried to amend Newton's law to fit the continuum, but he soon found it was a case of amending the continuum so as to fit Newton's law. Or rather, since a perfect fit was impossible, this being the cause of all the trouble, he amended the continuum so as to fit Newton's law in the only region where it could fit, namely, at infinity, and then found that the misfit for nearer distances gave just the needed 43″ a century for Mercury's orbit. And just as completely as, some three centuries earlier, the kinematical explanation of cycles and epicycles had crumbled to nothing in the hands of Kepler and Newton, so now the dynamical explanation of a gravitational force crumbled in the hands of Einstein. The story of this part of our Medallist's work has been so often told and is so familiar to all astronomers that you will hardly wish to linger over it. Let me only remind you that it opened up a path into entirely new scientific territory along which Weyl and others have advanced, attempting so far as can at present be seen with success, to extend Einstein's fundamental conceptions so as to explain the "forces" of electromagnetism in terms of a still further generalisation of the geometry of the continuum. If they have succeeded, the mechanism of the whole universe is transformed; dynamics disappear from science, and the laws of nature are those of geometry alone.

We need hardly spend time over the threadbare and rather meaningless question of whether our Medallist has performed the feat of "abolishing the ether." So much depends on what we mean by "ether." As soon as the term is defined, the question as to whether or not that particular ether exists almost answers itself —generally in the negative. The luminiferous ether of Kelvin, Maxwell, and Faraday, largely as the result of our Medallist's new outlook on the universe, may be described as dead; it is no longer a serious scientific hypothesis, but merely an item in the unscientific jargon of popular expositions of "wireless."

Let us rather spend the few minutes that remain in taking a glimpse of the new universe into which Einstein's work has led us.

Until the seventeenth century the majority of men believed that terrestrial life was the prime reason for the existence of the myriads of stars that lighted the firmament; they had indeed been created just a few days before man so as to be ready to minister to his pleasure on his arrival. In the twentieth century the majority of men believe that there is a sort of flow of time which is regulated by our consciousness. We live now in the year 1926, and therefore speak of 1925 as dead and past; 1927 is not yet born but will spring into life for us just as soon as we need it, which will be when we reach the end of 1926. So the traveller journeying west through Devon might suppose that Somerset had fallen out of existence at the moment he left it, and that Cornwall was waiting only for his arrival to come into existence. Foolish, perhaps, when expressed in terms of space, and yet our everyday belief in respect of time.

Einstein's theory eliminates the supposed essential difference between space and time; what is one man's space is another man's time. Not only so, but what is the past in time for one man is the future for another man. According to the view thrust upon us by the theory of relativity, the space-time landscape does not spring into life in front of us and die behind us; it is unalterably there. Existence becomes a picture rather than a drama, and the year 1927 has the same sort of existence as the county of Cornwall. Probably no one would regard this as a final statement of the matter; it goes as far as the theory of relativity carries us, but the theory of relativity is concerned only with inanimate nature; it takes no cognizance of life or consciousness. It is for us to go further if we can.

Does the theory, however, leave room for us to go further? Does it leave room for life and consciousness, and for the attributes, such as free-will, which we attach to them?

The materialistic philosophy of a generation ago used to insist that the picture which science then presented of the universe left no room for such things. That picture has no doubt been torn to shreds, but what about the new picture? Does this look with any more favour on our instinctive belief that we can guide our actions and make the universe in some small degree different by our presence? Or are we mere passive spectators, carried—in a train whose speed we cannot regulate and whose course we cannot alter by an inch—out of Devon with which we can do

nothing except gaze at it through a window, into a Cornwall which is already in existence and has been unalterably created by other hands than ours? To this last question the answer of the theory of relativity would seem to be in the affirmative, but relativity is not the whole of natural science; it is not even the whole of our Medallist's work.

His contributions to science fall into two columns which, unhappily, are parallel and show no signs of meeting. The first column contains his contributions to the Theory of Relativity, the red-letter years being 1905 and 1915; the second column contains his contributions to the Theory of Quanta, the red-letter years being 1905 and 1916. It is not yet altogether clear which of these columns will figure most prominently in the history of present-day science when this is finally written in its proper perspective. But it already seems possible that the second column of our Medallist's work may contain the needed antidote to the determinism and automatonism to which the first column, if it stood by itself, would seem to condemn us.

This room contains, let us say, a thousand atoms of uranium. The chances are that after five million years only 999 of these will be left, the other one having been transformed into an atom of lead, eight atoms of helium, and about 10^{-27} grammes of radiation or heat. One of the thousand atoms is fated to be transformed in this way, but what determines which particular atom it is to be? Are we tempted to conjecture that it will be that one that gets most knocked about in the interval, or that gets into the hottest places, or what not? If so, we are wrong; for if blows or heat could disintegrate the one atom they could also disintegrate the other 999, and yet every physicist is firmly convinced that no possible treatment can retard or expedite the disintegration of the uranium atoms in the least degree. Once every five million years fate knocks at the door of one atom and it breaks up. Why fate chooses this interval, why she selects one particular atom rather than its fellow we simply do not know; we seem to be beyond the domain of what have heretofore been called natural laws.

Now let us think of a more familiar, although more complicated phenomenon. The hot filament of an electric light bulb receives energy from a dynamo and discharges it as radiation. Inside that filament the electrons of millions of atoms are jumping up and

down between different energy levels, and our Medallist has investigated what may be called the statistics of their jumping about. Most of the knocks now are just those of ordinary radiation. The temperature radiation of the filament knocks some electrons up and some down; double the stream of radiation and the electrons will be knocked up and down twice as frequently. But this is not the whole story: if it were, the emission of light from the filament would not be what exact experiment shows it to be. Our Medallist finds that to explain the observed stream of radiation from the filament, fate must be invoked here also. Some atoms are knocked down from the high energy level to the lower because the stream of radiation pushes them down, but others stumble down by processes analogous to those by which the uranium atom disintegrates. They stumble, if you like, of their own clumsiness, or, if you like, because fate beckons them down. Put it anyhow you like, and you will almost certainly be wrong; our Medallist has shown that it happens, and beyond this we know nothing.

But it is, I suppose, clear that we may be in the presence of something here which is quite beyond the inflexible cause and effect of the older mechanics, and possibly equally beyond the precreated tangle of events of the theory of relativity. A single instance will perhaps suggest how far beyond. The lines of the hydrogen spectrum result from the falling down of the electrons of hydrogen from one energy level to another, and in the determination of the wave-lengths represented by these lines the future of the atom enters as an equal partner with the past, although, as we have seen, the future of an individual atom can no longer be regarded as a consequence of its past in the sense in which an effect is the consequence of the cause. We are here in unfamilar regions of thought where our minds get frozen and refuse to operate. But one thing at least seems possible. It seems as though the deadly inevitability of cause and effect has ended, and we are in the presence of new possibilities of freedom which as yet we do not understand. Our Medallist's work on Relativity changed the universe from a drama into a picture. It seems possible, as Weyl first suggested, that his work on Quanta may have provided the clue which is destined to change it back again into a drama—no longer a drama in which all the parts have been written and the gestures pre-arranged before the curtain went up, but a drama in which

all the actors choose their actions as the play proceeds—in fact, not a staged drama but life. No doubt the great mass of the universe must always follow a predestined path; nothing but predetermined forces can bind the cluster of the Pleiades or loose the bands of Orion or guide the Bear with her train, but there is now, for the first time since Newton, room in the universe for something besides predestined forces. No doubt this is only a possibility, only a conjecture if you like. We do not understand quantum phenomena well enough to go beyond conjectures. Perhaps a hope is dawning that some quite recent investigations of an abstruse mathematical nature are going to provide an answer to the puzzle, but if so it seems probable that the answer will not be in terms of ordinary time and space, and so will come from outside the regions surveyed by the theory of relativity. In any case, it seems that there must be room for much in the universe about which relativity knows nothing. Perhaps the two columns of our Medallist's work, which never clash because they never meet, provide a true symbolical picture of the universe which he has done so much towards elucidating.

We all regret he has been unable to come to receive the Medal in person. We have received the following letter from him:

(*Translation*)

To the Royal Astronomical Society.

Gentlemen.—He who discovers a line of thought which permits us to penetrate even a little deeper into the eternal mystery of Nature is greatly privileged. He who, in addition, is encouraged by recognition, sympathy and help from the best minds of his time, enjoys almost more happiness than one man can bear. In this spirit I thank you from the bottom of my heart for the great honour of which you have found me worthy. I should have wished to come to you in person to receive the Gold Medal, but unfortunately it is impossible for me to do so.

With distinguished esteem,

A. EINSTEIN.

The medal will be sent to him, and with it, I am sure, goes the most cordial wish of the whole Society that the future may bring with it health, vigour, and further scientific triumphs of the kind that have already made him one of the outstanding figures of modern science, and, I think we may anticipate the verdict of posterity and add, one of the outstanding figures also in the history of human thought.

THE NEW IDEAS IN METEOROLOGY*

By G. C. SIMPSON.

THE first quarter of the twentieth century will always be remarkable for the great advances made in science. In our own particular branch the advance has probably been the most startling and has appealed very strongly to the popular imagination. In mathematics we have had a little-known and even less-understood branch of pure mathematics applied to physical problems with results which have revolutionized our whole conception of the universe in which we live. In astronomy we have had described to us an evolution of the heavenly bodies as real and as dominating as the evolution which the previous century revealed in the animal kingdom. In physics the progress made has been most remarkable. At the beginning of the century, it is true, we had been introduced to the electron, to Röntgen rays, and to radio-activity; Planck was also writing on the laws of radiation; but no one realized the powerful tools which these phenomena were going to put into the hands of physicists. These tools have, however, been used, and not least by our own countrymen, to dig deep into Nature's secrets, even into the atom itself, so that now we are able to visualize the component parts of an atom, which itself is a structure far removed from our powers of perception.

Meteorology, although a child of applied mathematics and physics, has scarcely been touched by the epoch-making discoveries in the house of its parents. The quantum has found no place in our theories of the mechanism of the atmosphere; a knowledge of the structure of the atom has not helped us to understand the physics of the air as we deal with it in meteorology; the relationship between mass and charge, the invariability of the velocity of

*From the presidential address delivered at Southampton on August 28, before Section A (Mathematical and Physical Science) of the British Association.

light, four-dimensional space and all the other new conceptions which have been responsible for the advance of physics, have been of no help to meteorologists in their especial branch of science.

The whole attention of physicists has been so dominated by these new ideas, and the vistas of unexplored country which they have opened out are so vast, that it is no wonder that physicists have had no interest in a domain in which their new tools could not be employed. The consequence has been that meteorology has had little help from physicists and mathematicians as such, and has had to depend, at least in Britain, on the relatively small band of meteorologists in Government employ. Let me say, however, that we are grateful for the help which we have received from physicists, especially from those who were brought into contact with meteorology during the War. In spite of the fact that meteorology has not been able to make use of the recent discoveries in pure physics, there has been in the last twenty-five years as fundamental a revolution in our ideas of the atmosphere as has taken place in our ideas of electricity and matter. Unless I am very much mistaken, however, these fundamental changes in our conception of the atmosphere, both as a whole and in its parts, are little known outside the small band of professional meteorologists. I therefore welcome this opportunity of bringing them before the members of Section A of the British Association.

The Thermal Stratification of the Atmosphere

The fact that the temperature of the air decreases as we ascend in the atmosphere has been known from time immemorial, but our real knowledge of the temperature of the free air dates only from 1898, when Teisserenc de Bort introduced his *ballons-sondes*, which carried self-recording instruments to heights in the atmosphere up to that time never attained and from which no information was then available.

The initial success of Teisserenc de Bort in his epoch-making discovery of the stratosphere attracted great attention to his investigations. His methods were introduced into other countries, and an intense investigation of the upper atmosphere, with an International Commission to guide and encourage it, was inaugu-

rated. In Britain, Mr. W. H. Dines did Trojan service in the cause, and his observations and deductions are outstanding in the mass of data accumulated in many parts of the world. Naturally the conditions over Europe and North America were investigated in the greatest detail, but every opportunity has been taken by meteorologists to obtain upper-air data from all parts of the world. In addition to the regular observations undertaken in most countries having an organized meteorological service, expeditions have gone out specially to investigate the upper atmosphere over the oceans and over tropical Africa, and nearly all recent polar expeditions have included this investigation amongst their scientific activities.

There are, of course, large tracts of the earth's surface above which no observations have yet been made, but some, if only a few, observations have been made in all meteorologically important areas, including both polar regions. It is on the results of these observations that we base our conception of the thermal structure of the atmosphere, and meteorologists have attempted from them to generalize the conditions in all parts of the world. The most important generalization of this kind has been made by Sir Napier Shaw and published in the form of diagrams in his book, "The Air and its Ways."

Probably everyone here is familiar with the main results of these investigations. The atmosphere, which itself is an extremely thin film of air, is composed of two shells surrounding the earth. In the lower of these shells, called the troposphere, the temperature decreases as one rises in the atmosphere, and the air is warmer over the equator than over the poles at corresponding heights. In the upper shell, called the stratosphere, the temperature conditions are entirely different. There is little or no change in temperature with height, and the horizontal change of temperature is reversed, the temperature at the same height in the stratosphere decreasing as one passes from the poles to the equator. At the earth's surface the mean annual temperature near the equator is 27° C., and at the poles —23° C.; *i.e.* the equator is 50° C. warmer than the poles. At twenty kilometres above the surface the temperature over the equator is —80° C., and over the poles —30° C.; that is, the temperature difference between the equator and the poles

is the same in amount at the surface and at a height of twenty kilometres, but in the former case it is the equator which is the warmer, while in the latter it is the polar regions—a truly remarkable reversal.

The surface of separation between the two shells, called by Sir Napier Shaw the "tropopause," is extremely sharp. There is no region of transition. The stratosphere sits on the troposphere like a layer of oil on a layer of water. The boundary is, however, not horizontal, and therefore not exactly concentric with the earth's surface, being higher at the equator than at the pole. In other words, the lower atmospheric shell, the troposphere, is thicker at the equator than at the poles. At the equator it is nearly twenty kilometres thick, while at the poles it thins down to a layer less than six kilometres thick in the summer and less than four in the winter.

I have already said that in the troposphere the temperature decreases as one ascends. The magnitude of this decrease varies from place to place and from time to time, but one remarkable result has come out of the investigation, and that is that the average decrease is practically the same in all parts of the world. Near the ground the conditions are complicated; here the rate of decrease is largely affected by such factors as the kind of surface whether land or water, the time of day and the time of year. If we omit for this reason the two lower kilometres of the atmosphere, we are able to state that the rate of decrease of temperature with height, to which I shall refer as the "lapse rate," is the same in all parts of the world, from the equator to the poles. The lapse rate is not the same at all heights, but increases regularly as one ascends. Between two and four kilometres above sea-level the rate of decrease is 5.6° C. for each kilometre of ascent; the rate is greater at greater heights, until towards the top of the troposphere, say between six and eight kilometres, the rate is 7.1° C. per kilometre.

The importance of these results lies in the bearing they have on the possibility of vertical motion in the atmosphere. Whether air will rise or fall as the result of differences of temperature depends not only on an initial difference of temperature but also on the lapse rate in the surrounding atmosphere. When dry air rises

its temperature falls on account of adiabatic expansion 10° C. for each kilometre of ascent. From the observed values of the lapse rate given above, it will be seen that if a mass of air is as much as 10° C. warmer than its surroundings it cannot rise much more than two kilometres before it has no buoyancy left. The question of ascending and descending air is, however, very complicated on account of the condensation of the water vapour carried with it. The vertical motion of the atmosphere cannot be determined simply from consideration of the lapse rate of temperature in the atmosphere. We have also to take into account the pressure and vapour content of the moving air. This can best be done by considerations of entropy.

Sir Napier Shaw has prepared diagrams showing the entropy throughout the normal atmosphere. These show surfaces of constant entropy which are nearly horizontal, but they slope upwards from the equator to the poles, especially in the lower layers. If these surfaces could be made visible, we should see a series of layers lying one above the other like the strata in a geological specimen of stratified rock.

In all movements of the air in which heat is neither added nor extracted—for example, by condensation or radiation—it must travel along an isentropic surface. Even if condensation takes place, the amount of heat added is usually so small that the air can only move to a neighbouring isentropic surface slightly higher in the atmosphere. These isentropic surfaces act like physical restraints to the air, tending to prevent its moving in any but an almost horizontal direction. The effect is almost exactly as though the atmosphere were definitely stratified in nearly horizontal planes, so that all motion of the air must take place along the strata in which it started.

This is what I mean by the thermal stratification of the atmosphere, and it is a new idea in meteorology, for it rules out ascending and descending currents as a direct consequence of the normal temperature distribution in the atmosphere. That ascending currents do occur and play a large part in atmospheric processes is, however, a matter of both observation and inference. We can actually see them taking place whenever we observe well-developed cumulus clouds, and we infer them from the large

amounts of precipitation which we measure, for appreciable precipitation can only be accounted for on the assumption that air is rising in the atmosphere and cooling by adiabatic expansion. These ascending currents are possible in the stratified atmosphere only if the air taking part in them receives sufficient heat on its ascent to raise its entropy at least to that of the surrrounding atmosphere at each level. Heat is supplied by condensation of water vapour, but normally air does not hold sufficient water vapour, even when saturated, to supply the requisite heat, and so cannot pierce the normal stratification. It sometimes happens, however, that the stratification is less pronounced than at other times. The greater the lapse rate the less the stratification, and by increasing the lapse rate sufficiently the stratification can be reduced to such an extent that there is sufficient water vapour to supply the heat required. When this occurs the atmosphere becomes unstable to saturated air and ascending currents take place, generally with considerable violence.

Such conditions give rise to thunder-storms, which occur, as is well known, only when the lapse rate has been abnormally increased, generally by the heating of the surface layers faster than the layers higher in the atmosphere. Also in equatorial regions over the ocean, where the air is very hot and also very humid, there may be sufficient water vapour in the air for it to rise through the normal stratification. This is the origin of the squalls and heavy rain in the Doldrums. From this it will be seen that the ascent of air through its environment is not a normal phenomenon, but does occasionally occur in special circumstances.

The descent of air is an entirely different matter, for there is no process which extracts heat from a descending current equivalent to the process of condensation which supplies heat to an ascending current. Yet air cannot descend through the stratification without the necessary heat being extracted. On the other hand, we do know that air descends, for the air which goes up in the ascending currents, or rather an equivalent amount, must come down somewhere. The solution of the problem is that air practically never descends through its environment, but comes down by the gradual subsidence of a whole column. This is generally brought about by the air at the bottom of the column

spreading under the surrounding air and so lowering the air above in a way to be described in greater detail later.

If now we consider the undisturbed atmosphere in different parts of the world, we find that each has its own stratification, which is mainly determined by the local radiation. At the equator the stratification is not so close as at the poles, and equivalent strata are higher in the atmosphere the farther we move from the equator. If a large mass of air is transported as a whole without gain or loss of heat, no change in entropy occurs, and therefore it retains its original stratification. It is therefore clear that if masses of polar and tropical air are brought together the strata will not fit. The process is something like removing two geological specimens from different parts of a stratified rock and then placing them side by side. We can recognize the surface where the two masses meet by the discontinuity in the strata; in geology such a surface of discontinuity is called a fault. We shall consider later the consequence of bringing together masses of air of different origin in this way, and it will be shown that they interact like separate fluids, but throughout the resulting motion they retain their stratification, although this stratification becomes modified and distorted.

This idea of the stratification of the atmosphere which has caused us to recognize that ascending and descending currents are relatively rare occurrences raises new problems as to how the solar energy is converted into the kinetic energy of winds. This leads me to the second subject of this address.

The Mechanism of the Atmospheric Heat Engine

Brunt has calculated from considerations of wind and atmospheric friction that 25×10^{11} kilowatts of energy are required to maintain the motion of the atmosphere. It is generally agreed that this energy is derived from the solar radiation which falls on the earth, the atmosphere itself acting as a gigantic heat engine to convert the solar energy into the kinetic energy of the winds. How the atmospheric heat engine works is the problem which we are now to discuss.

Until quite recently this problem seemed to present no difficulty.

All atmospheric motion was referred in one form or another to the ascent of warm air through cold air and the descent of cold air through warm air. The so-called general circulation of the atmosphere was considered to be the direct consequence of the ascent of warm air at the equator and the descent of cold air at the poles, there being a permanent circulation from the equator to the poles in the upper atmosphere, with a return flow in the surface or middle layers. Similarly cyclones were considered to form in regions where the air is warmer than the surrounding air, with a consequent upward motion of the warm air through its colder environment. The anticyclone, on the other hand, was considered to be a region of cold descending air. Thus cyclone and anticyclone were regions of ascent of warm and descent of cold air respectively.

I have already shown, however, that the thermal stratification of the atmosphere, except in the Doldrums and occasionally in other regions, is prohibitive of such ascending and descending currents. Further, observations have shown that there is no direct flow of air from the equator to the poles in the upper atmosphere, and measurements of temperature in cyclones and anticyclones have shown that the former are not warm and the latter are not cold.

Although the old ideas were wrong in detail, they were, of course, right in principle, for the potential energy inherent in masses of air at different temperatures must be the origin of the kinetic energy of the winds, the difference in temperature between the equator and the poles being responsible for the general circulation of the atmosphere and the difference in temperature between neighbouring masses of air for the energy of cyclones and anticyclones. The only question is, how does the transfer from potential to kinetic energy take place?

The solution of the problem was given by Margules in a series of papers, commencing in 1903, in which he investigated the energy developed in storms. Margules' work leads to an entirely new idea as to the method by which solar energy is converted into the kinetic energy of atmospheric motion. Instead of warm air rising vertically like the warm gases in a chimney, drawing air in at the bottom and delivering it at the top, we see two bodies of air, one warm and the other cold, brought side by side, then the

cold mass slowly subsiding and pushing its way as a wedge of cold air under the warm air, which is partly raised and partly drawn in above to replace the cold subsiding air. In the process the centre of gravity of the whole moving mass is gradually lowered, so providing the energy for the motion which we recognize as winds.

The essential difference between the new and the old idea is that the two masses of air, in which the difference of temperature is the cause of the motion, never mix. We start with the two bodies of air side by side, with a surface of sharp discontinuity between them. In each body there is a different stratification of isentropic surfaces. In the warm body of air the corresponding isentropic layers are all lower than in the cold body of air. As the cold mass subsides its isentropic layers are lowered, while as the warm air is raised its isentropic layers are raised with it; but the surface of discontinuity between them, which I have previously likened to a geological fault, is a sliding surface, and no air crosses it. The sliding motion does not cease until either the corresponding isentropic layers on the two sides have joined up across the surface, which then ceases to be a surface of discontinutiy, or until all the warm air has been raised above the cold air and the surface of discontinuity becomes a horizontal plane. The two masses are then in equilibrium without any mixing having taken place.

Surface of Discontinuity

The process which I have just described would take place very rapidly on a stationary earth, and in a short time the surface of discontinuity would disappear in the manner described or appear as a horizontal surface with all the cold air underneath and all the warm air above. But in the atmosphere we find inclined surfaces of discontinuity persisting for days together, and others which are apparently permanent. This arises from the effect of the rotation of the earth, which we have so far neglected, but which introduces new forces when air is in motion.

A mathematical investigation of the conditions governing the air motion at surfaces of discontinuity has shown that, on a rotating earth, the tendency of cold air to pass under warm air can be completely counterbalanced by forces due to the earth's rotation if

the air on the two sides of the surface has suitable relative velocities.

We owe the mathematical investigation of this problem chiefly to Helmholtz, Margules, V. Bjerknes, and Exner.

Two bodies of air at different temperatures will remain in equilibrium side by side if suitable motion parallel to the boundary is given to the air on each side. The angle which the surface of discontinuity makes with the horizontal depends on three factors, namely, the latitude and the difference in temperature and relative motion of the warm and cold currents. Given steady motion, these three factors adjust themselves in a perfectly definite way, with the cold air lying as a rule in the acute angle which the boundary makes with the horizon.

V. Bjerknes considers that there are three great permanent surfaces of discontinuity of this kind in the atmosphere, and that the slope of the surface in each is in accordance with the discontinuities of the wind and density observed on the two sides. Taking these in turn, the first is the great surface of discontinuity between the troposphere and the stratosphere. The second surface of discontinuity is between the trade winds and the anti-trade winds above them. Bjerknes' third surface of discontinuity, which has received the name of the "polar front," is a very important one in modern meteorological theory. On the whole there is very little air motion in polar regions, and the cap of air over each pole is losing heat by radiation and so tending to subside and flow away from the pole. As the air from the polar cap flows radially outwards it is deflected to the west on account of the earth's rotation. On the other hand, in middle latitudes, from near latitude 30° to the polar circle, the air is moving in an almost unbroken stream from west to east. Relative to the air in the polar cap this air is very warm. We therefore have a cold cap of westerly-moving air embedded in a warmer mass of air moving towards the east, and between the two there must be a pronounced surface of discontinuity. In such conditions the surface should slope upwards toward the pole. V. Bjerknes considers that there are such surfaces of discontinuity associated with each pole and that they are very stable. These "polar fronts" play a large part, as we shall see later, in Bjerknes' theory of the formation of cyclones.

But these are not the only surfaces of discontinuity which

play a very real part in the physics of the atmosphere. While the three surfaces just described are of a more or less permanent nature, we now recognize a constant succession of temporary surfaces of discontinuity which form and pass away in our own latitudes. Their presence is revealed in many ways. On the synoptic charts lines can be drawn which divide regions in which the conditions at the surface as regards temperature, humidity, and wind velocities are entirely different. These lines are simply the intersection at the earth's surface of the surface of discontinuity between two bodies of air.

The Origin and Structure of Cyclones

The old idea of a cyclone was tersely expressed by Sir Oliver Lodge, in a letter to the *Times* last year, as follows: "A cylindrical vortex with its axis nearly vertical, rolling along at a rate conjecturally dependent partly on the tilt, and with an axial uprush of air to fill up a central depression, which depression, nevertheless, was maintained and might be intensified by the whirl, the energy being derived from the condensation of vapour." If this were the true mechanism of a cyclone we should expect to find considerable symmetry around the axis. The air would move in a continuous stream circulating around the centre but always approaching it; in other words, the stream lines would be continuous spirals. There would also be little difference of temperature in the different parts of the cyclone, for the same air current would pass successively through all parts. In reality the conditions are entirely different. When stream lines are drawn by the aid of the wind arrows on synoptic charts it is impossible to connect them so that they circulate all round the depression; we find, on the contrary, that they are discontinuous, the stream lines in certain parts meeting the stream lines in other parts almost at right angles. Also we find large discontinuities in the temperature, each set of stream lines having its own temperature. Further, we find that the areas of rainfall are not confined to the central regions, but are broad bands radiating from the centre like spokes in a wheel, showing that the ascending air is not taking place mainly in the central region.

As the result of recent work we now recognize a structure in a cyclone which was unknown a few years ago. We owe this new knowledge largely to the work of J. Bjerknes and his assistants in the Bergen Geophysical Institute.

We are being forced more and more to recognize in cyclonic depressions the meeting-place of polar and equatorial air. Each body of air is stable to vertical currents within itself, but where the two masses meet, readjustment is necessary; the surfaces of discontinuity tend to set themselves at the angle necessary for stability under the existing condition of velocity and temperature. This involves the bodily raising of the warm air over the cold air and a general sinking and spreading out of the cold air. The energy for the process is derived from the conversion of potential energy into kinetic energy, as the centre of gravity of the air as a whole is slowly lowered during the readjustment of the air masses. The energy derived from the condensation of water vapour is a very insignificant part of the energy developed in a cyclonic depression.

It must be admitted that we are still far from a complete understanding of the mechanism of cyclonic depression; on the other hand, we now know some features which are common to all depressions, and we have a much clearer idea of the source of the energy and the conditions necessary to their production. We have to imagine that in polar and tropical regions the air is relatively stagnant, and so has an opportunity to reach the state of thermal equilibrium appropriate to those regions. As already stated, the atmosphere is only a thin film, and we picture large areas or slabs of this film breaking away from their proper locality and moving into middle latitudes. Apparently the detached films move as a whole, at least to a considerable distance within the stratosphere. When two such portions of the atmospheric film come into juxtaposition they are not in equilibrium relative to one another, and readjustment must take place. The surface of contact remains more or less intact, but the cold air tends to sink and undercut the warm air, while the warm air slides up the surface of discontinuity. The whole motion takes place on the revolving surface of the earth, and the forces called into play by this revolution result in the air movement taking place in what appears to

be a great vortex. The energy of the winds is derived mainly from the readjustment of the centre of gravity of the air mass considered as a whole, although the latent heat of condensation provides some additional energy by supplying heat to the warmer air as it ascends the slope of the surface of discontinuity. It will be admitted, I think, that this is a radically new idea regarding the mechanism of a cyclone.

All that I have said so far refers to the cyclonic depressions of middle latitudes. As to whether the mechanism of tropical cyclones is the same or whether we have here something more of the nature of the process described by Sir Oliver Lodge, meteorologists are not yet agreed We need more observations especially of the conditions in the upper air over tropical cyclones, before this question can be decided. At present we must leave it an open question.

These new ideas have had a far-reaching effect on the practical applications of meteorology, especially in the domain of weather forecasting. The old method of weather forecasting was mainly empirical and based on the work of Abercrombie. Abercrombie had sketched the distribution of weather about centres of high and low pressures, and forecasting was based on the determination of the movement of these pressure distributions when they appeared on the weather chart, the assumption being made that as the pressure system passed over a place the normal sequence of weather would be experienced.

Now the forecaster has much more knowledge of what I may call the anatomy of a depression. The pressure distribution is of course still the main factor, but the forecaster searches his chart for indications of the surfaces of discontinuity, and examines the characteristics of the air masses to see whether they are of polar or equatorial origin. In this way he is able to determine the structure of the cyclone and whether it is developing or dying. Having determined where the surfaces of discontinuity are situated, he is able to say where rain may be expected, and he knows what weather changes will accompany the passage of each surface of discontinuity as it moves over the surface of the land. He is aided in this by observations taken in the upper atmosphere by means

of pilot balloons and aeroplanes fitted out with meteorological instruments.

This has all resulted in greater confidence in the forecasts made, a confidence which is frequently justified by remarkably accurate forecasts. Unfortunately, the processes which take place in the atmosphere are extremely complicated, and perfect forecasts are still far from being attained. The progress made, however, is very encouraging, and, what is still more important, the paths along which further investigation must be made are clearly defined. Many more observations of the upper air are necessary, many more theoretical investigations have to be made in the quiet of the study, and there is room for many more experiments in the laboratory.

REVIEW OF PUBLICATIONS

Meteors by Charles P. Olivier, Ph.D., Associate Professor of Astronomy at the University of Virginia and Astronomer at the Leander McCormick Observatory. 276 pages, 23 plates, 6¼ × 9½ inches. Baltimore, The Williams and Wilkins Co., 1925. Price $6.00.

This is the first general treatise on meteoric astronomy published since 1871 and it supplies a great need. Moreover Professor Olivier is eminently qualified for the task of writing it. For many years he has assiduously observed and investigated meteoric phenomena. At the meeting of the International Astronomical Union at Cambridge in 1925 he was chosen chairman of the section on shooting stars, succeeding the veretan W. F. Denning, who began observing meteors in 1866 and became one of the most distinguished of British amateur astronomers.

The book contains twenty-four chapters, the titles of which are: Historical Introduction; How Meteors are Observed; Comets; The Leonids; The Perseids; The Lyrids; The Bielids or Andromedes; The Halley's Comet Meteors and the Pons-Winnecke Comet Meteors; Radiants; Do stationary Radiants Exist? Suggested Explanation of Stationary Radiants; Apparent Paths of Meteors within the Atmosphere; Meteor Trains; Computation of Real Heights of Meteors; Computation of Orbits of Meteors; Apparent Distribution of Meteors in Time and Space; Formation of Meteor Streams; Perturbations of Meteor Orbits; Influences of Meteors upon the Earth; Discussion of the Formation of the Bielid and Perseid Streams; Meteorites; Are Lunar Craters Meteoric in Origin? Origin of Meteors; Fireballs and Meteorites; Conclusion.

From this list it will be seen that the subject is discussed form every point of view and the treatment is able and scholarly through-

out. The ordinary amateur will be able to read much of the book, but there is in it a considerable amount of technical matter adapted especially to the professional astronomer.

The author has much to say about radiants and his opinions on them and the interpretation of observations on them differ widely from those of some other writers on the subject. He shows his scientific attitude of mind when he states: "It is clearly to be understood that the opinions here expressed supersede any formerly published by him, as in more than one phase of the subject longer study and experience have caused him very considerably to modify those previously held."

The references to original sources are numerous and constitute a valuable feature.

About the only criticism the present writer would make is in regard to the pictures distributed through the book. There are twenty-three plates, but only a few of them have any direct connection with the subject, and not a single reference in the text to any of them could be found. On the other hand many illustrations appropriate to the subjects discussed could be found—for example, the observations of the Leonids in 1799 and 1833. If some of the finely executed plates had been omitted it might have been possible to reduce the price and thus to allow a large general circulation, which it certainly deserves but which, it is to be feared, it may not have.

C.A.C.

Annual Tables of Constants and Numeriacl Data; Numerical Data of Spectroscopy. 350 pages, $8\frac{1}{2}\times10\frac{1}{2}$ inches, Paris: Gauthier-Villars; London, Cambridge University Press; Chicago, University of Chicago Press.

This portion of volume 5 of this publication contains the numerical data for emission spectra, the Zeeman phenomena and absorption spectra. It was prepared by L. Bruninghaus and gives the results published for the years 1917 to 1922, inclusive. Primarily, it is an index and digest of all the papers published in the period. These have been collected from some 47 publications, the numerical results being extracted and arranged in convenient form for consultation. Workers in the field will appreciate the

convenience of such a publication. In all cases the references from which the data are taken are placed at the beginning so that the reader may consult the original publication if he desires. The book practically becomes a summary of the known numerical spectroscopic data up to the year 1922 owing to the great number of papers included and owing also to the fact that most authors give a comparison of their results with former work on the same element. Some stellar spectroscopic results are also included, but this part of the volume does not cover the field to nearly the same extent as that for the laboratory spectroscopy. The work is published by the International Committee elected by the Congress of Applied Chemistry held in London, June, 1909. *General Secretary Ch. Marie, 9 Rue Bagneux, Paris (VIe).*

R.K.Y.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

From "The Humorist"

The Soviet officials have ordered a telescope that will be powerful enough to bring the moon exceptionally close. Maybe their idea is to show their followers what they once promised them.

A Brilliant Aurora

On the evening of Wednesday, April 14, a fine aurora was seen in Toronto. It covered almost the entire sky and there was considerable apparent motion though it was difficult to estimate the focus of the streamers. The display was seen over a large area of the country and undoubtedly the magnetic elements were strongly disturbed, though no reports thereon have so far been received. At times the curtain form was seen, tinged at the lower edge with orange-red. Dr. E. A. Smith, of Secaucus, N.J., in a note to the Editor states that the display was one of the most brilliant ever seen in that part of the country. Between 9.45 and 10.30 p.m. it was exceptionally bright. He states also that since January 2 the aurora has been seen seven times over New Jersey.

Russia to Have the Largest Refractor

In Plate I in this issue is a view of two large discs of glass in the optical shop of Sir Howard Grubb, Parsons & Co., Newcastle-on-Tyne, England. They were made by the Parsons Optical Glass Co., of Derby, and from them a lens of 41 inches aperture will be produced. It will form the objective of a telescope for the Russian Soviet Government.

Information regarding it has been supplied to "Science Service" by A. Ivanoff, the director of the well-known Russian observatory at Pulkovo.

In 1912 the Russian Government ordered from the firm of

Grubb and Son, in Dublin, a photographic refractor of aperture 32 inches and focal length 35 feet. The war and subsequent events prevented its execution, but in 1922 the Soviet Government renewed the order.

The mounting, dome and rising floor were completed by the Grubb firm before its liquidation, but the discs for the lens could not be obtained. Then Sir Charles Parsons took over the firm and undertook to secure the discs and they were produced by the Parsons Optical Glass Co., but instead of being 32 inches in diameter, a 42-inch pair was made. So it was agreed to have the aperture 41 inches and to use the mounting already constructed, that is, to have a focal length of 35 feet. This is in marked contrast to the great Yerkes refractor which has an aperture of 40 inches, and a focal length of 62 feet. The lens will be achromatic for wave-length 4500 A.

Originally it was intended to place the instrument at Nikolaieff, near Odessa, but now it is proposed to locate it at Simeis, on the north coast of the Crimea, 60 kilometres east of Sebastopol. The dome and rising floor have already been taken there, but the mounting will remain in England for testing the objective.

The Simeis branch of the Pulkovo Observatory enjoys excellent atmospheric conditions, and a large reflector having an aperture of 40 inches, also by Grubb, is already installed there.

Later.—It is reported that the 42-inch discs have been found useless. The writer hopes that this is not the case, but if unfortunately it is he predicts that this will be just one more obstacle for Sir Charles Parsons to overcome.

Further Ether Drift Experiments

In a recent issue of this Journal (page 1 of this volume) Dr. R. K. Young gave a brief history of experiments made to detect the motion of the earth relative to the ether, especial attention being devoted to the experiments of Prof. D. C. Miller at Cleveland and on Mount Wilson. As is well known, Einstein based his Theory of Relativity upon the conclusion drawn from Michelson and Morley's experiments, that it was impossible to detect any motion of the earth with respect to the ether; while Miller, performing similar experiments on Mount Wilson apparently did find

a motion, the amount of it being about one-third of that calculated. Naturally this result led to serious questioning of the solidity of the foundation upon which Einstein built his remarkable structure.

Now Michelson's experiments were not the only ones which had been made to detect the predicted drift. But they had all been made near sea-level, and they had all been decisively negative. In view of Miller's apparent success with the interferometer when tried at an altitude of 6,000 feet, it was evidently an interesting problem to perform these other experiments at a high elevation.

Some of them have been tried recently by Dr. Rudolph Tomaschek of the University of Heidelberg, Germany, and his results have been reported by "Science Service."

Dr. Tomaschek performed two sets of experiments, in each of which he used a charged electrical condenser. Such a condenser when moved as rapidly through the ether as the earth is supposed to carry it should give rise to an appreciable magnetic field. He tried the experiments at altitudes of 65 feet, 1,850 feet and 11,400 feet—the latter being on the Jungfrau, one of the highest peaks of the Alps. No effect was observed.

The other experiment was first performed by Trouton and Noble, at the University of London, in 1903. A light disc-shaped condenser was suspended by a fine wire by means of which it was charged electrically and about which it was free to turn. According to theory, when such a condenser is moved through the ether, it should tend to turn in an endeavour to place itself at right angles to the direction of the motion. The apparatus was constructed so as to be sensitive enough to detect a motion of the earth relative to the ether much smaller than that indicated by Miller's result. The disc was hung with its plane in the direction of the supposed drift, and the experimenters sought to detect any slight turning of the condenser. Trouton and Noble had not been able to detect any motion in 1903 and Tomaschek was equally unsuccessful at any altitude.

This is evidence in favour of Einstein's fundamental hypothesis, but Miller's results are still to be accounted for.

C.A.C.

MEETINGS OF THE SOCIETY

AT TORONTO

February 23,—The regular meeting was held in the Physics Building at 8 p.m., the President, Mr. A. F. Hunter, in the chair. The following were elected members of the Society:—

George W. Johnson, Summerland, B.C.
Percy J. Batkin, 12 Vimy Ridge Ave., Toronto.
George H. Barrett, 579 Palmerston Ave., Toronto.
Mr. F. E. Biss, 72 Amroth Ave., Toronto.
Miss Madelaine Davis, St. Hilda's College, 99 St. George St., Toronto.
Miss Lillian Duggan, 46 Bleecker St., Toronto.
Mr. W. M. Ferguson, 588 Clinton St., Toronto.
Miss Hankins, 200 Scarboro Road, Tononto..
Miss Ruth Hubbert, 152 Westminster Ave., Toronto.
Mr. Joseph W. Long, 126 Dovercourt Road, Toronto.
Miss Henrietta MacCallum, 21 Maple Ave., Toronto.
Dr. E. A. McCullough, 165 St. Clair Ave., W., Toronto.
Miss Ethel Messervy, B.A., 48 Willcocks St., Toronto.
Mr. H. Stamper, 76 Adelaide St. W., Toronto.
Miss Ada Utting, 1 Willcocks St., Toronto.

The assistant librarian reported 78 periodicals since the last report was given, made up as follows:—Canada and the Empire, 32; United States, 28; other countries, 18.

Prof. H. A. MacTaggart addressed the meeting on "The History of spectacle lenses," pointing out that this subject has a mechanical part and an astronomical part. There is a further division of the subject of spectacles into (1) the medical side, (2) the physical aspect of the quetsion, and (3) the making of lenses. The use of lenses began with Ptolemy, and Roger Bacon added to the theory of their action. The real inventor of spectacle lenses was an Italian, Salvino, who is claimed as the originator of them. In the earliest times the mounting of them was in leather, bone, and finally in metal. In the first days of their use glasses for spectacles were made at Venice, also at Nuremburg, at Regensborg (Ratisbon) and in Spain. Thread spectacles were in use at an early date. England and France took part in their use and manufacture quite early. In the United States Benjamin Franklin devised bifocal spectacles, and Thomas Young, in England, was the first to make astigmatic lenses for spectacles. The manufacture of spectacle lenses is attended with difficulties, as the glass has to be

cooled very slowly so as to anneal it properly, and so optical glass is very expensive. The use of polarized light in the examination of optical glass to test it for strains introduced by hasty cooling, was described and illustrated by the speaker. The address was well illustrated by an interesting series of lantern slides, which made it instructive and entertaining.

Mr. A. F. Miller read a translation which he had made of an article from *L'Astronomie*, "The Theory of Eternal Return, and Astronomy" by Pierre Salet, of the Observatory of Paris. In 1871, ten years before Nietzsche gave the name of "The Eternal Return" to the theory, Louis Auguste Blanqui, the French anarchist and communist, when shut up in a dungeon at Fort Taureau for political offences, composed a curious pamphlet called "Eternity by the Stars" in which he put forward what was essentially the same idea. Notwithstanding that Blanqui was an agitator and concerned in the cummunistic depredations at Paris, he deserves to have his name attached to this theory. Blanqui assumed that space is Euclidian, i.e., it is without limit, and time is also limitless. The article is a summary of Blanqui's pamphlet which he composed in 1871 in prison. The theory of Einstein fixes a limit to space, but that of Blanqui does not.

March 9,—The regular meeting was held in the Physics Building at 8 p.m., the President, Mr. A. F. Hunter, in the chair. The minutes of the preceding meeting were confirmed.

The following were elected members of the Society:—

A. C. Gifford, M.A., F.R.A.S., Wellington, New Zealand.

Donald MacGillivray, LL.D., Shanghai, China.

Prof. C. A. Chant reported seeing Mercury on March 5, at Centreville, about 15 miles south of Peterborough, about 7.15 p.m. The Zodiacal Light was seen at the same place and time and was very distinct, reaching up almost to the Pleiades. Dr. Geoffrey Bell also reported seeing Mercury, at Paris, Ont., on March 4, for almost half an hour. As the most easterly elongation of the planet does not take place until the 14th, this proves to be an opportune time to observe it. Mr. A. F. Miller reported that sunspots have been fairly numerous recently.

The paper of the evening was by Mr. A. F. Miller on "Pepys as an Astronomer, and the Science of his Time." Samuel Pepys, who is best known for his famous Diary, was born in 1633 and lived for 70 years. His father was a tailor in Brampton, Eng., and during the infancy of Samuel, the family was moved to London. He was married at the age of 22 to a French girl of 15 years. At the time he commenced his Diary in 1659, he was then living in a London garret. He had a minor position in the Exchequer, with a small salary of not more than £20 a year. The Diary, which extends over a period of ten years, covers an epoch replete with events of the utmost importance—the end of the Protectorate, the return of the monarchy, the plague of London when 70,000 people perished, the great fire of London, two wars with the Dutch of Holland, the incorporation of the Royal Society, and the founding of Greenwich Observatory with Flamsteed

as Astronomer Royal. Pepys' cousin, Sir Edward Montague, was his patron, and through him Pepys had promotion. Montague was the man who brought back the king from Holland, and with Montague Pepys went to sea as an officer in the Admiralty, although he could not add the simplest sum in arithmetic nor did he know the multiplication table. But he set to work and learned the science of navigation (a mathematical subject). In those days, besides the compass there were in use the quadrant (for latitide determinations), the log (still in use at the present day), and the lead (for sounding the depth of the sea). Pepys saw the famous comet of 1664, which had a tail ten degrees in length, and becoming anxious to learn astronomy he secured a telescope. A textbook by Joseph Motson, printed in 1674, was dedicated to Samuel Pepys, who was by that time Secretary of the Admiralty. It was a handbook on the use of globes, treating of gnomics, also of astrology, although the writer had little faith in that branch. Astronomy was at that time based on the Ptolemaic system. Mr. Miller possesses a copy of this book, which he brought to the meeting for the members to examine. The influence of the church over astronomical views was then great. The ablest French astronomer of the time, Cassini, was non-committal, and even Descartes had to narrow his views to suit the church dogmas. John Evelyn, the diarist, was a friend of Pepys, and Dryden was also a close friend. Halley, Newton and Hadley, the inventor of the sextant, were contemporaries.

March 23,—The regular fortnightly meeting was held in the Physics Building, the President, Mr. A. F. Hunter, in the chair.

The President announced the death of Mr. J. Wicksey who held the position of attendant of the rooms in which the Society meets.

Under the heading of Observations, Mr. A. F. Miller remarked the rapid fall of the barometer from the morning of the 22nd March until noon of the 23rd, a variation of over one inch during 24 hours, and gave some interesting figures showing the immense change of pressure on the human body; the pressure would represent a total weight equal to about 1½ tons, and the work done in the motion of the atmosphere would be equivalent to that of removing 8 inches of shale rock and replacing it. He thought this sudden change of pressure would have an injurious effect on people with weak hearts.

Prof. Chant had observed the planet Mercury on the 20th March, remarking the extreme northerly position. He also expressed his pleasure in the knowledge that the art of large telescope making is reviving in England. Sir Chas. Parsons, of turbine fame, has established works in Newcastle in co-operation with Howard Grubb, of Rathmines, near Dublin, Ireland. Curiously enough, one of their first commissions is the construction of the 41 inch objective for the Soviet Government of Russia, which will be the largest refractor in existence when completed. It is not a paying venture, but Sir Charles, with commendable public spirit, is using part of his fortune in this way.

Mr. J. R. Collins drew attention to Prof. D. C. Miller's researches and his conclusion that our galaxy is moving toward the region of the constellation Draco at the rate of 120 miles per second.

The address of the evening was given by John Patterson, M.A., F.R.S.C., on "Water Vapour in the Atmosphere." He showed that all the vagaries of the

weather were caused by the presence of water vapor in the atmosphere. In fact, without this element, temperature readings would be identical on the corresponding days each year. In the atmolphere there are 21 parts of oxygen, 78 of nitrogen and one part of water vapor, carbon dioxide, argon, and other rare gases. The water vapor amounts to about one part in 400. The amount of water vapor in the atmosphere is limited by temperature. At 32 degrees F. a cubic mile of air holds 22,000 tons of water vapor, at 80 degrees 100,000 tons, but at zero only 5,500 tons.

Water vapor is also essential to life. The Earth's surface presents about three times as much water as land, and Mr. Patterson thought it possible that the greater proportion of water is necessary for life in the processes of nature. Small globular particles of water floating in the air give fourfold saturation, compared with a level surface. He also referred to Dr. Abbot's investigation of the amount of radiation received from the sun, but pointed out the extreme difficulties in long range forecasting of weather, the solar constant being only one factor.

The water vapor in the atmosphere causes the winds. Winds are the chief agency for the ditribution of water vapor over the surface of the globe. In the conversion of water vapor into rain, the dust particles in the air play a part. The particle forms the nucleus fo the rain drop. He showed that warm air is capable of retaining moisture to a much greater degree than cold air, so that a sudden drop of temperature in the air will condense the water particles. An ordinary gale or rainstorm represents energy equal to 800 million h.p. working for a year. Hailstones are the result of an uprushing current of air at high velocity, carrying with it the descending raindrops. Reaching high altitudes, these drops are frozen. When the air current is spent the frozen drops would fall, but only to be caught up again in another uprush. This performance might be repeated a number of times; each time the drop would gather to itself more water vapor, becoming frozen as a layer, until when heavy enough to overcome the resistance of the wind, it falls to the ground as hail.

A small particle of water of the smallest size contains about 20,000 molecules of water vapor. Humidity reaches a limit when saturated air holds 100 per cent. In this connection the hygroscopic qualities of substances play a part. Hygroscopic substances come into play more actively at certain seasons of the year, for example—Indian summer. Fog particles vary in size from 1–1000th to 1–20th of a centimetre. The biggest raindrops are about 1–5th of an inch or ½ cm. in diameter. A big drop falls at the rate of about 25 feet a second, but it does not fall if the upward rush of the wind is above that rate. The size of hailstones depends on the upward rushing winds.

Mr. Patterson described the relation of humidity to forest fires, which are most active from 2 to 5 in the afternoon. A low humidity reading is serious as a fire hazard. In this connection the Meteorological Service can be of great assistance to the government forest rangers in predicting humidity conditions.

At the close, Mr. Patterson showed some beautiful lantern pictures of snow crystals, enlarged by microphotography.

A. KENNEDY, *Recorder.*

The Royal Astronomical Society of Canada

OFFICERS FOR 1926

Honorary President—Hon. G. H. Ferguson, K.C., B.A., LL.D., Minister of Education for Ontario
President—A. F. Hunter, M.A., Toronto
First Vice-President—Wm. Bruce, J.P., Hamilton
Second Vice-President—R. K. Young, Ph.D.
General Secretary—F. T. Stanford, Toronto
General Treasurer—H. W. Barker, Toronto
Recorder—A. Kennedy
Librarian—Prof. C. A. Chant
Curator—Robert S. Duncan
Council—Mgr. C. P. Choquette, M.A., Lic.Scs., Montreal; J. B. Fraser, M.D., Toronto; R. A. Gray, B.A., Toronto; A. R. Hassard, B.C.L., Toronto; J. H. Horning, M.A., Toronto; Dr. Ralph DeLury, Ottawa; Prof. John Matheson, M.A., Kingston; Sir Joseph Pope, K.C.M.G., Ottawa; John Satterly, M.A., D.Sc., Toronto; Dr. D. M. Wunder, Toronto; and Past Presidents: John A. Paterson, M.A., K.C.; Sir Frederic Stupart, F.R.S.C.; A. T. DeLury, M.A.; Louis B. Stewart, D.T.S.; Albert D. Watson, M.D.; Allan F. Miller; J. S. Plaskett, B.A., D.Sc.; J. R. Collins; W. E. W. Jackson, M.A.; R. Meldrum Stewart, M.A.; and the Presiding Officer of each Centre as follows: C. R. Coutlee, C.E., Ottawa; Col. W. E. Lyman, Montreal; Rev. T. W. Morton, B.Sc., Winnipeg; Prof. P. H. Elliot, Victoria, B.C.; H. R. Kingston, M.A., Ph.D., London.

OTTAWA CENTRE

President—C. R. Coutlee, C.E.
Vice-President—H. M. Ami, D.Sc.
Secretary—A. W. Grant, B.A.
Treasurer—J. F. Fredette, D.L.S.
Council—W. W. Nichol, M.A.; J. S. Lane, B.A.; F. Henroteau, D.Sc.; and Past Presidents: R. M. Stewart, M.A.; J. J. McArthur, D.L.S.; R. E. DeLury, M.A., Ph.D.; and R. J. McDiarmid, M.Sc., Ph.D.

MONTREAL CENTRE

Honorary President—Mgr. C. P. Choquette, M.A., Lic.Scs.
President—Col. W. E. Lyman.
1st Vice-President—Rev. W. T. B. Crombie, M.A.
2nd Vice-President—H. E. Asbury
Treasurer—Prof. A. J. Kelly
Secretary—Miss A. Vibert Douglas
Council—Prof. A. S. Eve, Prof. A. H. S. Gillson, H. W. Jesmer, Justice E. E. Howard, Geo. Sample, Julien C. Smith

LONDON CENTRE

President—H. R. Kingston, M.A., Ph.D.
Vice-President—Mrs. W. E. Saunders
Secretary-Treasurer—E. T. White, B.A., D.Paed.
Council—Rev. R. J. Bowen, F.R.G.S.; T. C. Benson; Mrs. J. C. Middleton; W. A. McKenzie; E. H. McKone, B.A.

WINNIPEG CENTRE

President—Rev. T. W. Morton, B.Sc.
Vice-President—Mrs. E. L. Taylor
Curator—L. A. H. Warren, M.A.
Treasurer—Mr. H. B. Allan
Secretary—Mrs. S. C. Norris, 569 Sherburn St.
Council—N. B. MacLean, M.A., D.S.O.; D. P. Morse, C.E.; N. R. Wilson, M.A., Ph.D.; J. H. Kolb, Cecil Roy, A. W. Meggett and C. F. Ellis (*Asst. Sec.*)

VICTORIA CENTRE

Honorary President—J. S. Plaskett, D.Sc., F.R.S.
President—Prof. P. H. Elliot, M.Sc.
Vice-President—K. M. Chadwick
Secretary-Treasurer—R. G. Miller
Recorder—R. M. Petrie
Council—E. E. Blackwood, J. P. Hibben, J. A. Pearce, H. H. Plaskett, and Past Presidents: F. Napier Denison, W. S. Drewry, J. E. Umbach, W. E. Harper, M.A., and J. Duff, M.A.